STATISTICAL CHARACTERISTICS OF SMALL SCALE WIND-WAVES AND THEIR MODULATION BY LONGER GRAVITY WAVES AND ATMOSPHERIC FORCING

Tetsu Hara
Graduate School of Oceanography
University of Rhode Island
Narragansett, RI 02882
phone: (401) 874-6509, fax: (401) 874-6728, e-mail: tetsu@ripples.gso.uri.edu
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LONG-TERM GOAL

The long-term goal of this study is to understand the interaction between ocean surface roughness and various oceanic and atmospheric variables. Such knowledge is essential for further improvement of microwave remote sensing of ocean surface features, and advancement of various studies on air-sea interaction processes.

SCIENTIFIC OBJECTIVES

The objective of this research is to extend our study of the dynamics of wind-generated gravity-capillary waves to include new scientific issues. They are, interaction between surface roughness and wind variability, modulation of short wind waves by long waves, and comparison with microwave backscatter. Comparison with other field observations will also be made.

APPROACH

To investigate effects of wind variability, we investigate real time series of wind variability and the wave field. The specific procedure will be: a) identify a typical time scale of wind gusts (estimated to be tens of seconds to minutes) from observation, b) investigate the response of short wind waves in the same time scale, c) examine possible feedback of the time varying roughness to winds.

We continue to investigate the modulation of short wind waves by intermediate/long gravity waves. We have established a method to calculate long wave frequency spectra (Hanson, et al., 1997). Our efforts during this program is to combine the SLSG data with the long wave time series to examine the MTF by dominant gravity waves.

We have initiated comparison between our SLSG data and the ship-board microwave measurement by Dr. Lyzenga. Comparison with SAR/RAR imagery is also underway. Our objective is to clarify how the surface features observed by such radar systems actually compare with the real modulation of short wind-waves. We will calculate omnidirectional wavenumber slope spectra of capillary-gravity waves over a short integration time in order to investigate small scale variabilities.

The study is a joint effort between Dr. Erik J. Bock (WHOI), Dr. James Edson (WHOI), and myself. Other co-investigators include Dr. Rick Chapman (JHU/APL), and Dr. David Lyzenga (U.Mich/ERIM).

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WORK COMPLETED

We have completed the analysis of the short wind wave spectrum from the ONR High-Resolution ARI as well as the joint ONR-MBL/NSF-CoOP experiment. The results will appear in (Hara, et al., 1998).

We have completed the calculation of directional spectra of dominant gravity waves and the calculation of the MTF using the data from the High-Resolution ARI as well as from the ONR-MBL/NSF-CoOP exeriment.

RESULTS

The results of wave slope spectra on clean water show a well-defined correlation with the wind friction velocity. However, our spectral values at higher wavenumbers are significantly higher than previous laboratory results (see Figure 1). In the presence of surface films wave spectra may decrease by more than one order of magnitude at lower wind stresses.

The dispersion characteristics of short waves vary markedly depending on the wavenumber, the wind stress, and the surface chemical condition. Some results in the presence of surface films at intermediate winds show much higher apparent phase speeds than the theoretical dispersion relation (see Figure 2). This may be because of an enhanced near-surface current or because of the relative increase of wave energy that is phase-locked to longer steep gravity waves.

IMPACT/APPLICATION

If the short wind waves in open ocean conditions are significantly different from those in wind-wave flumes, this fact should be incorporated in the interpretation of microwave radar remote sensing images.

TRANSITIONS

Our directional wave spectral analyses have been incorporated by other MBL/ARI investigators for the study of atmospheric turbulence in the wave boundary layer.

RELATED PROJECTS

We have been participating in the CoOP (air-sea gas exchange) program of NSF. The first CoOP field experiment took place in conjunction with the MBL West Coast Experiment in 1995, and the second field experiment took place in July 1997. The objective of our CoOP program is to study the effect of physical and chemical processes near the air-sea interface on the air-sea gas exchange in coastal waters.

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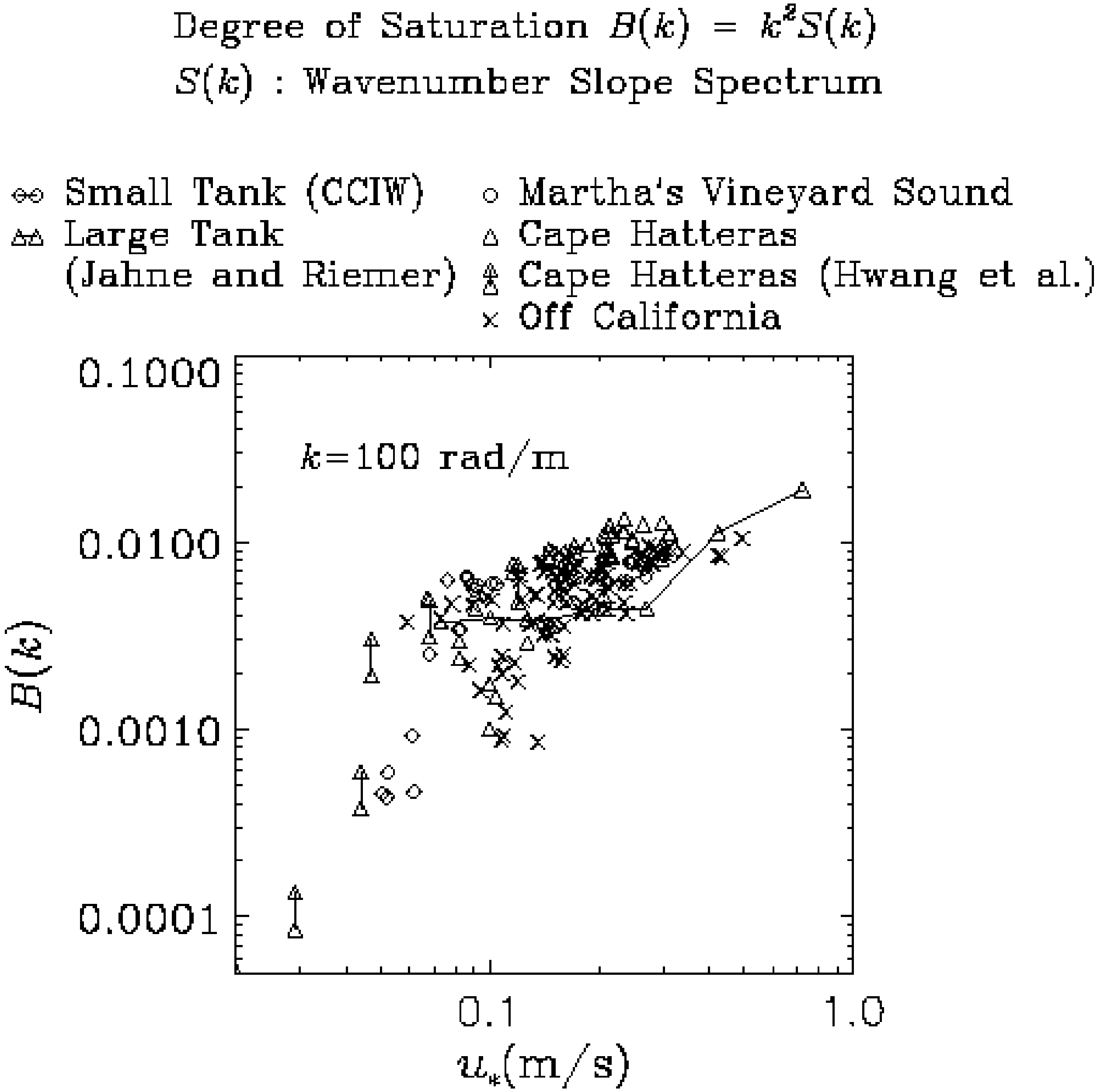
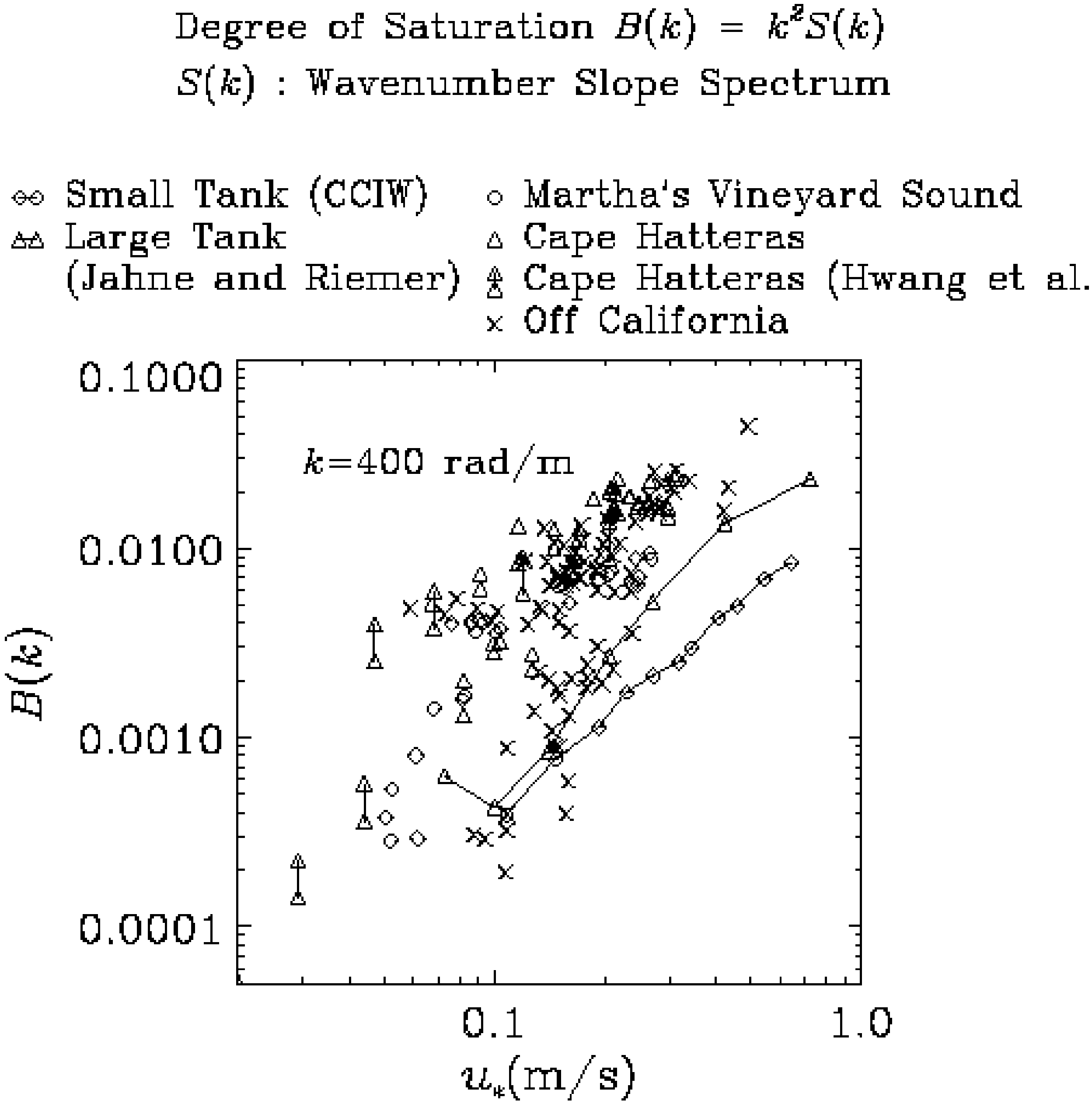
Jähne, B. K., and K. S. Riemer, 1990. "Two-dimensional wave number spectra of small-scale water surface waves," *J. Geophys. Res.*, 95, 11,531-11,546.


Degree of Saturation $B(k) = k^2 S(k)$
$S(k)$: Wavenumber Slope Spectrum
Small Tank (CCIW)
Large Tank (Jahne and Riemer)
Martha's Vineyard Sound
Cape Hatteras
Cape Hatteras (Hwang et al.)
Off California
k=100 rad/m
0.1000
0.0100
0.0010
0.0001
$B(k)$
0.1
1.0
u_*(m/s)

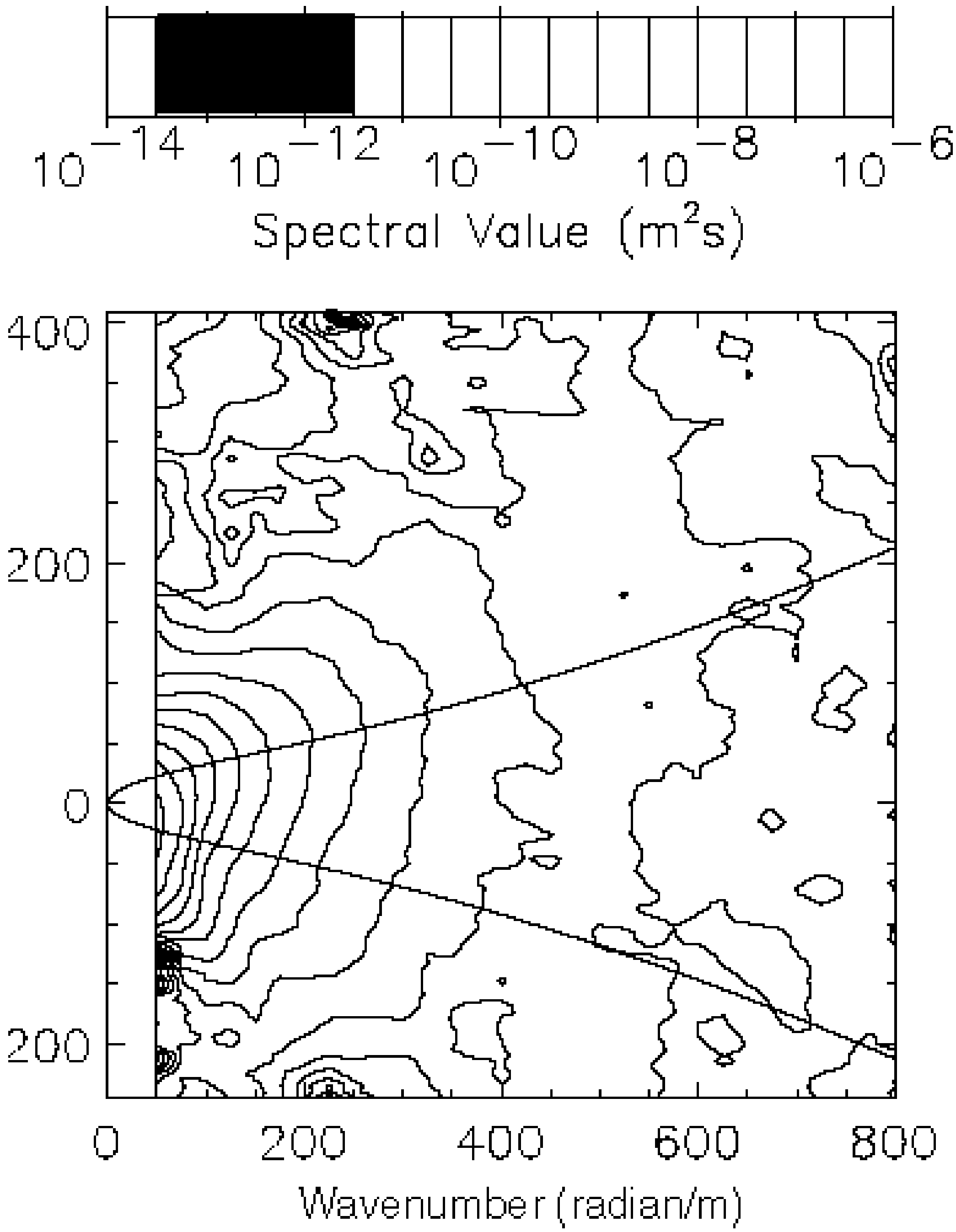
(A)


Degree of Saturation $B(k) = k^2 S(k)$
$S(k)$: Wavenumber Slope Spectrum
Small Tank (CCIW)
Large Tank (Jahne and Riemer)
Martha's Vineyard Sound
Cape Hatteras
Cape Hatteras (Hwang et al.
Off California
k=400 rad/m
0.1000
0.0100
0.0010
0.0001
$B(k)$
0.1
1.0
u_*(m/s)

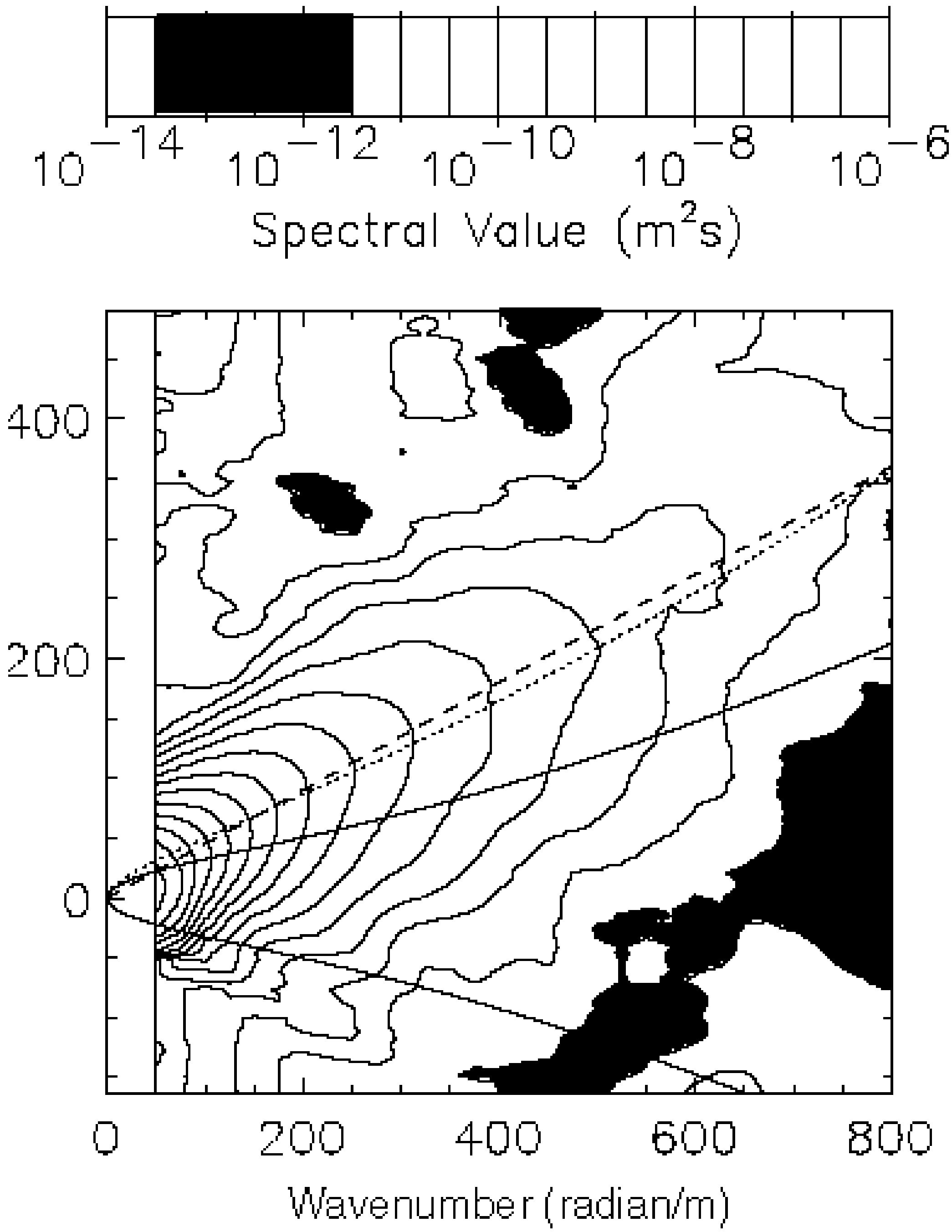
(B)

Figure 1.Omnidirectional Degree of Saturation versus Wind Friction Vel.(A) and (B), respectively

Crosses, Hara et al., (1998) (CoOP); triangles, Hara et al., (1998) (Hi-Res II); pairs of triangles connected vertically by solid lines, Hwang et al. [1996]; diamonds, Hara et al. (1994); triangles connected by solid lines, Jähne and Riemer (1990); diamonds connected by solid lines, Hara et al. (1997).


10^-14
10^-12
10^-10
10^-8
10^-6
Spectral Value (m²s)
400
200
0
200
0
200
400
600
800
Wavenumber (radian/m)

(A)



(B)

Figure 2. Wavenumber-frequency Slope Spectrum in Along-wind Direction Here u*=0.24 m/s. (a) Clean water. (B) With surfactant. Solid line, dispersion relation; dotted line, dispersion relation with surface drift 0.27 m/s; dashed line, phase speed of gravity waves of k = 49 rad/m.